expenditures at 25% per year and we do not consider the cost of the computer as part of the expenses for DSL but we do consider modem and inside wiring costs to be such costs.) A few of the cost elements (in particular, the OA&M cost per subscriber) appear not to vary in proportion to the specific activity. In that case, the value of the cost element can be set to zero.

Equipment costs are specified as time vectors over the ten years considered by the model. For example, we can be highly confident that the cost of a DSL modem will fall fairly rapidly over the next several years and the real cost of upgrading inside wiring will probably not fall significantly. The model permits such time variation of underlying costs.

iii. Expenses

The model permits assigning an associated operating expense to all capital investment. A common rule of thumb in the electronics industry is that hardware generates an operating expense of about one percent of the purchase price per month (electricity, repairs, etc.).
The model also incorporates an expense assignment to each of the following activities:

-supporting a preexisting subscriber over the course of a year,
-supporting a new subscriber over the course of a year,
-first-year administrative and startup expenses, and
-start up expenses associated with the first year of provision of xDSL service from a central office.

iv. Capital Recovery

The model stores two capital recovery rates for each class of investment. One capital recovery rate is based on historical regulatory practice for the class of equipment involved (OSP, circuit, etc.). The other capital recovery rate is designed to reflect the user's judgement about the appropriate rate for economic capital recovery. The model can be set to use either one capital recovery method or the other with the change of a single parameter. Consequently, it is easy to examine some of the consequences of alternate approaches to capital recovery.

v. Cost of Capital

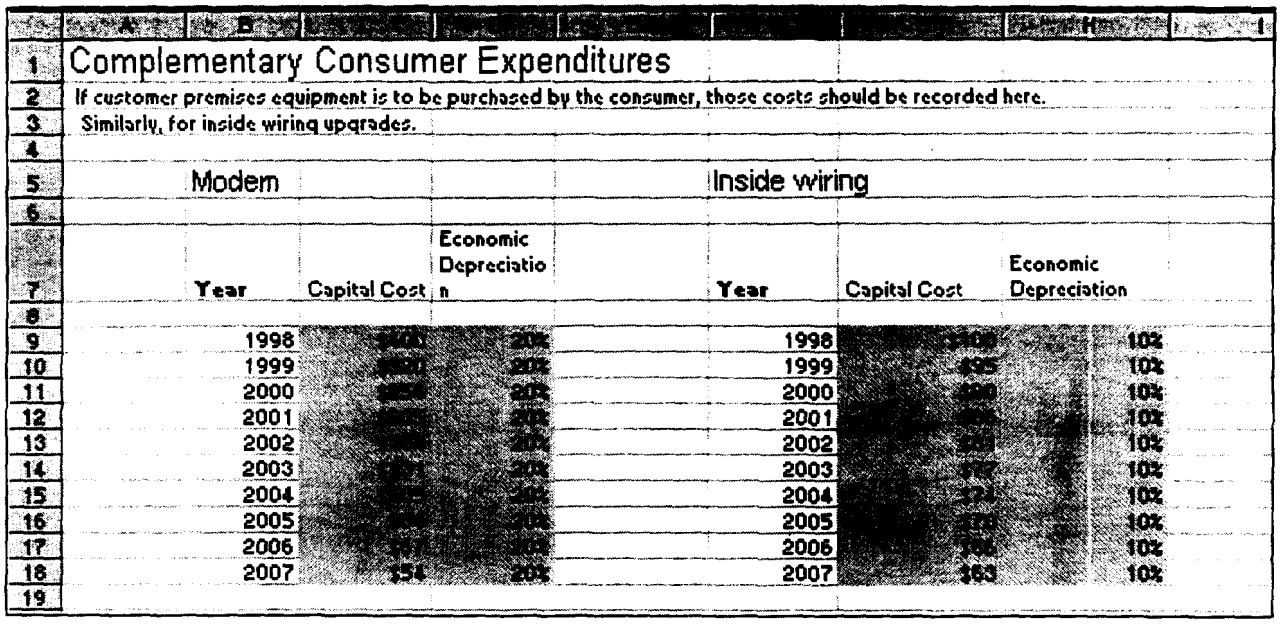
The model allows the user to specify both a market cost of capital and a regulatory cost of capital and to specify which should be used in the analysis. The selection variable that specifies either economic or regulatory depreciation also is used to control whether capital costs are calculated using the market or regulatory cost of capital.

### m. Incremental Cost Analysis

This sheet contains a duplicate of the Revenues and Expenditures sheet. However, if the IncAnal macro is executed, then the demand in each subregion in each year is incremented by one and the difference between the costs with and without the additional subscriber is calculated and stored. The results of such calculations are displayed on the xDSL Subscriber Economics sheet and Subscriber Economics Graphs. Notice that because of the assignment of support and marketing costs to first-year subscribers, incremental costs can exceed average costs in the later years.

### n. Complementary Expenditures

This sheet permits calculation of complementary expenditures by consumers. This allows the user to put the costs of xDSL service into context. A sample of that sheet is shown in Figure C-20.



Complementary Consumer Expenditures

If customer premises equipment is to be purchased by the consumer, those costs should be recorded here.
Similarly, for inside wiring upgrades.

| | Modem | | | Inside wiring | | |
|---|---|---|---|---|---|---|
| | Year | Capital Cost | Economic Depreciation | Year | Capital Cost | Economic Depreciation |
| 9 | 1998 | | 20% | 1998 | | 10% |
| 10 | 1999 | | 20% | 1999 | | 10% |
| 11 | 2000 | | 20% | 2000 | | 10% |
| 12 | 2001 | | 20% | 2001 | | 10% |
| 13 | 2002 | | 20% | 2002 | | 10% |
| 14 | 2003 | | 20% | 2003 | | 10% |
| 15 | 2004 | | 20% | 2004 | | 10% |
| 16 | 2005 | | 20% | 2005 | | 10% |
| 17 | 2006 | | 20% | 2006 | | 10% |
| 18 | 2007 | $54 | 20% | 2007 | $63 | 10% |

Figure C-20

### o. Market Share Calculation

This sheet contains the calculation of the fraction of the market and number of subscribers taking the xDSL services of the firm under analysis. As described earlier, demand modeling is divided into two separate elements. Primary demand, the number of xDSL subscribers in each year, is calculated as a function of prices and the total number of potential subscribers. The user provides information about the prices (over time) that will be charged for DSL service in each subregion by the firm under analysis and by the competitors. The competition model is then used to calculate the number of users who sign up with the firm under analysis and the number who sign up with competitors.

The calculation used to divide primary demand among the firms in the market makes that division according to price and an element of consumer inertia and performs a separate analysis for each of the three subregions. In the first year, consumers are assumed to make their decision on price alone. The market share of the firm under study is a linear function of the difference between the firm's price and the competitor's price. (For simplicity, we are describing the case with only a single competitor.) If the two firms have equal prices, then their market shares are equal. If the

price charged by the firm under study is more than a specified fraction, dP1, below the competitor's price, then the firm gets a 100% market share. If the price is between the lower limit and the equal price, the firm's market share varies linearly with the difference in prices. Similarly, there is another fraction, dP2, that is applied to the competitor's price. If the firm's price is more than (1+dP2) times the competitor's price, then the firm has a zero market share. This market model has the advantage of predicting that firms with close prices will have similar market shares, but allowing price differences to affect the market equilibrium. The user is permitted to set the parameters dP1 and dP2. One can think of this approach to price competition as an application of "fuzzy logic." If dP1 and dP2 are set to be quite small, then the model becomes a low-price-take-all market. In our initial runs, we have used values of dP1 and dP2 of 0.3, which makes the model price sensitive – but not overwhelmingly so. Figure C-21 below shows the market share of the firm under study as a function of the price it charges.

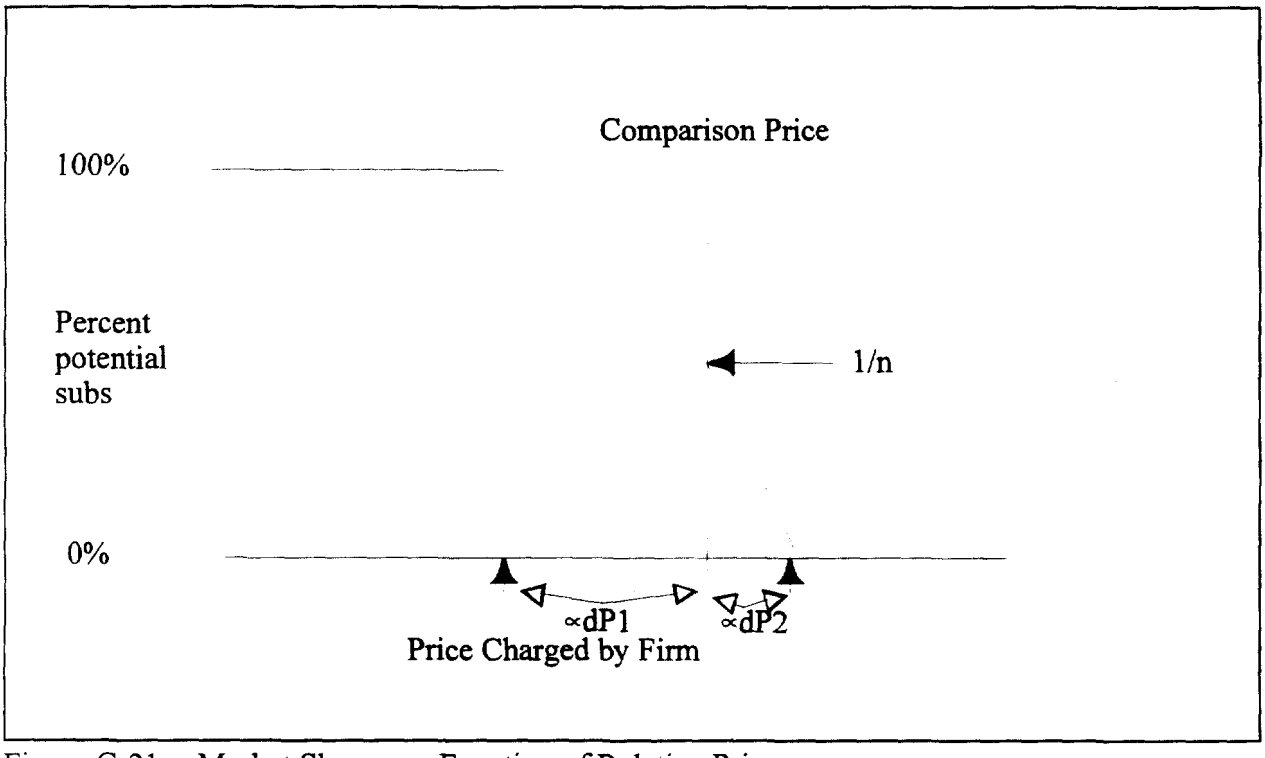



Figure C-21 Market Share as a Function of Relative Price.

In the second year, modeling the market becomes more complex. There are three categories of subscribers in the second year: (1) new subscribers who have come into the market, (2) old subscribers who have decided to shop around, and (3) old subscribers who stay with their current supplier. The number of new subscribers is simply calculated as the difference in the primary demand for year one and year two. These new subscribers are then assigned to one firm or the other based on the method that was used for all subscribers in year one (price competition). The model also requires the user to specify an inertia factor that describes the fraction of subscribers in year one who remain with their current supplier. The complementary fraction (1 - inertia factor) is the churn factor. The number of first-year subscribers is multiplied by the churn factor to determine the number of subscribers who become mobile. These subscribers elect to leave their current supplier and shop around. (One could consider these to be a mix of dissatisfied subscribers, people who move, and the curious.) These subscribers are then assigned to a firm using the price competition model that was used in the first year. If such a subscriber is reassigned to the firm under study, the marketing and administrative costs associated with a new subscriber are incurred (rather than the costs associated with a retained subscriber).

The inertia factor allows the firm to benefit from low prices in early years – generating consumers who remain with the firm for several years after its prices are no longer the lowest.

The demand information supplied also contains a specification of the region served by the firm under study. The specification of the region includes the number of central offices operating in the region in each year – subdivided into the number of central offices serving urban, suburban, and rural subscribers.

### p. Subregion calculations

Both demand and costs are divided into three categories – urban, suburban, and rural. Cost differences among regions depend on two factors – any differences in loop costs specified in the inputs and differences in the number of subscribers per central office. That is, differences between average costs in rural and urban areas can arise when the fixed costs of upgrading central

offices to support DSL service are recovered over relatively few subscribers as well as from any assumptions about differential costs of upgrading loops or of otherwise extending DSL service.

The model requires the user to specify the price charged by both the firm and its competitors in each of these geographic regions for each year considered. The model then calculates the number of subscribers for each central office for each year. The costs generated by attracting, supporting and providing service to these subscribers is then calculated. The model also calculates the incremental cost that would be created by one additional subscriber in each year by an additional subscriber in each subregion.

### q. Running the model

The model is a computer spreadsheet prepared in Microsoft Excel (version 7.0a). The data for individual runs can be entered on the subsheet labeled *Scenario Inputs*. All results except for incremental costs are normally recalculated immediately after the data are changed. Incremental costs are calculated by running the macro *IncAnal*.

The model is designed to be run in an interactive fashion. The user sets parameters, examines the output, adjusts the parameters, and examines the new output. For example, if the user wished to simulate rate-of-return regulation, he or she would set a price vector for the firm and its competition, set the allowed return, and indicate whether regulatory or economic depreciation was to be used in the analysis. The model would then calculate the firm's costs (including the cost of capital used in the DSL service). The user would then replace the prices with the costs so calculated (the copy command makes this step quite easy). Market shares and therefore per subscriber costs would change again. The user would iterate this process until costs and prices converged. At that point, a price vector has been identified that represents the effects of binding rate-of-return regulation (zero economic profit in each time period).

Similarly, if the user wished to examine the effects of geographic averaging imposed by regulators, the user would input a price vector for the firm that had the same price in each region.

The competitive prices could remain deaveraged, and the competitive performance of the firms could be compared.

### r. Conclusion

We have described a model designed to examine the effect of regulatory decisions, most notably control of retail pricing and capital recovery, on the health of the regulated firm supplying DSL services over the next decade. One of the purposes of such a model is to identify the effects of regulation on the incentives faced by such regulated firms when they consider whether to invest (and how much to invest) in DSL service. Clearly, many of the necessary inputs to such a model, such as the price of DSL modems in 2001, are necessarily speculative. However, because these speculative values are used in a consistent fashion, we believe that this model can be a valuable tool in comparing the effects of different regulatory regimes.

## Appendix D The Residential Demand for High-Speed Connections

Given the relatively recent development of the Internet and the even more recent development of widespread use of the Internet by households, there is only limited information on residential Internet demand use and even less information on the demand for high-speed digital services. Much of the information on Internet use comes from surveys in which respondents are self-selected, thereby imparting a substantial upward bias to the estimates.

Even more careful surveys of users and nonusers encounter problems of survey bias and sampling error because many households do not wish to participate in such surveys and even those who do participate may find it difficult to answer accurately the survey questions dealing with Internet or on-line service use. Many if not most Internet and on-line services now permit a household unlimited use for a flat monthly fee, thereby eliminating the need for the household to maintain an accurate notion of its use. In addition, those households whose members value time highly - a obviously critical determinant of the demand for high-speed usage — are likely to be underrepresented in any survey, even if the survey oversamples high-income households in an attempt to obtain a representative number of completed surveys from these households.

### s. The Growth of the Internet

Because Internet hosts must be registered, there are very good data on the growth of Internet hosts. The Internet began its remarkable growth in the late 1980s. In early 1989, there were only about 100,000 hosts. By January 1998, there were more than 29 million hosts.[37] A loglinear plot of this growth shows that the growth has not been diminishing, but continues to grow at an annual rate of about 60% per year (See Figure 5-1 below).

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[37] Network Wizards reports that of these 29 million hosts, only about 5 million would respond to inquiries by the ping utility. Obviously, some are behind firewalls, offline or otherwise unreachable.

Of course, the growth in Internet domains tells us little about Internet usage — particularly by households. The growth in Internet hosts or domains clearly reflects growth in the potential usefulness or attractiveness of the Internet to businesses and consumers alike, but it does not provide a measure of the extent or intensity of consumer interest in the Internet. Nor does it suggest anything about the value of greater speed in accessing the Internet.

### t. Consumer Ownership of Personal Computers

Access to the Internet or other on-line services currently requires the use of a computer. The Current Population Survey has been collecting data on household computer use since 1989. In 1989, only 8.2% of households had a computer; by 1989, the share had grown to 15%; and by 1993, 22.8% had computers. (**Table Appendix D-1**) Similarly, the most recent Department of Energy survey of households, undertaken in 1993, found that 23.3% of households owned a personal computer. By 1996, however, surveys by both PNR and Associates and Nielsen Media Research show that more than 40% of households had a computer. This suggests that in just three years, household computer penetration had almost doubled.

**Table Appendix D-1**
**Home Computer Ownership, 1984, 1989, and 1993 (% of Households)**

| Year | Current Population Survey | Department of Energy | Nielsen Media Research | PNR |
|---|---|---|---|---|
| **1984** | 8.2 | | | |
| **1989** | 15.0 | | | |
| **1993** | 22.8 | 23.2 | | |
| **1996** | NA | NA | 39 | 43.6 |
| **1997** | NA | NA | 41.3 | NA |

Source: Current Population Survey; Energy Information Administration, *Household Characteristics, 1993*; Nielsen Media Research, *Home Technology Report*, March 1996 and March 1997; PNR and Associates, Request III, May 1996.

Not surprisingly, the share of homes with a PC rises sharply with household income. The proportion rose from less than 10% for those with incomes of less than $15,000 per year to 45% for those with an income of $50,000 or more, according to DOE's 1993 survey. More recently, in March 1997, Nielsen found that only 20% of households with income below $10,000 per year had home computers and 55% of those with incomes above $50,000 had home computers.[38]

The CPS survey also found that access to a computer – whether at work, at home, or at school – has increased rapidly for all ages and demographic groups. In 1984, only 9% of persons 18 or over had access to a computer; in 1993, nearly 36 had access to a computer. The growth rate is similar for all races or ethnic groups – White, Black, and Hispanic. Nearly two-thirds of those with access to a computer use a computer at home. The Nielsen survey found that access to a home computer rose from 39.5% of those surveyed in July-August 1995 to 41.4% of respondents in March 1997.[39]

To use the Internet, home computers must generally be equipped with a modem that translates the analog telephone signal into a digital signal that computers can read and vice versa. These modems may or may not be connected to second residential telephone line. PNR found that 25.7% of households had modems for their home computers in 1996, but only 14.3% of households had a second telephone line. These second lines could be used simply as second voice lines or as lines to connect a modem and/or a fax machine.

In its March 1997 survey, Nielsen found that 29% of households had computers with a modem. More important, the share of home computers equipped with a modem increased from 59.9% in July-August 1995 to 71.4% March 1997, a period of 19.5 months. In both surveys, 27% of computer households indicated that they had purchased a computer within the last year. In addition, 27% of home computers with a modem had a modem speed of 28.8 kbs or 33.6 kbs.

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38 Nielsen Media Research, *Home Technology Report*, March 1997.

39 Id.

Moreover, the age distribution of home computers appeared to be almost identical in the July-August 1995 and the March 1997 surveys. Nearly half of all computer households had bought a computer within the past two years. These data point to a rapid replacement (or augmentation) rate for home computers, with virtually all new additions coming with a modem that is at or very near the current technological state of the art.

### u. Patterns of Household Computer Use

The use of a computer rises sharply with family income. Among persons aged 18 or over, computer use was only 11.4% in 1993 for those with family income of less than $10,000 per year. Computer usage rose to 36.5% for persons from families with median income ($25,000-$34,999) and to 65.4% for those from families with income of $75,000 or more. More important for this study, the availability of a computer at *home* rose from 6.8% to 61.7% for persons from the lowest and highest income classes, respectively. However, it appears that only about two-thirds of persons with access to a computer at home actually used it in 1993 (**Table Appendix D-2**).

Table Appendix D-2
Computer Use by Family Income Level for Persons Age 18 or Older, 1993 (%)

| Family Income | Uses a Computer | Has a Computer at Home | Uses Computer at Home |
|---|---|---|---|
| **Less than $10,000** | **11.4** | **6.8** | **4.4** |
| **$10,000-$14,999** | **15.2** | **8.4** | **5.3** |
| **$15,000-$19,999** | **23.0** | **12.5** | **7.6** |
| **$20,000-$24,999** | **27.7** | **15.3** | **9.5** |
| **$25,000-$34,999** | **36.5** | **21.2** | **13.2** |
| **$35,000-$49,999** | **46.3** | **31.3** | **19.5** |
| **$50,000-$74,999** | **60.3** | **45.9** | **29.8** |
| **$75,000 or more** | **65.4** | **61.7** | **40.4** |
| **Undisclosed Income** | **24.4** | **20.2** | **10.0** |

Source: Current Population Survey, October 1993

The availability of a home computer and the propensity to use it is related to both to age and to educational attainment. The 1993 Current Population Survey found computer use rises slightly with age through middle age, but declines thereafter (**Table Appendix D-3**). However, the more recent Nielsen Media Research Survey found that frequent computer use rises over the entire age distribution for males and declines only marginally for women over 54. When asked whether they had used a home computer "today or yesterday," nearly 70% of all males using a home computer responded affirmatively, but only approximately 50% of women responded yes (**Table Appendix D-4**).

**Table Appendix D-3**
**Computer Use by Age, 1993 (%)**

| Age | Has a Computer at Home | Uses Computer at Home |
|---|---|---|
| 18 to 21 years | 30.4 | 18.2 |
| 22 to 24 years | 25.4 | 16.8 |
| 25 to 34 years | 25.3 | 17.9 |
| 35 to 44 years | 34.2 | 22.4 |
| 45 to 54 years | 34.4 | 21.1 |
| 55 to 64 years | 19.9 | 10.7 |
| 65 years or older | 8.4 | 3.3 |

Source: Current Population Survey, October 1993.

**Table Appendix D-4**
**Frequent Computer Use by Home Computer Users, 1997 (%)**

| Home-Computer Users by Demographic Group | Used Home Computer "Today or Yesterday" |
|---|---|
| Teens 12-17 | 54.3 |
| Men 18-34 | 70.7 |
| Men 35-54 | 63.3 |
| Men 55+ | 70.2 |
| Women 18-34 | 48.2 |
| Women 35-54 | 54.6 |
| Women 55+ | 47.4 |

Source: Nielsen Media Research, *Home Technology Report*, March 1997.

Income is a more powerful determinant of both computer ownership and use. Persons with a college education are far more likely to own a computer and to use it than are noncollege

graduates **(Table Appendix D-5)**. In 1993, 80% of all home computer use by persons 18 years of age and over was undertaken by persons with at least some college education.

**Table Appendix D-5**

**Computer Use by Educational Attainment, Persons 18 Years and Older, 1993 (%)**

| Education | Has a Computer at Home | Uses a Computer at Home |
|---|---|---|
| **Less than 9th Grade** | **4.5** | **0.5** |
| **9th to 11th Grade** | **8.1** | **3.1** |
| **High-School Graduate** | **16.7** | **7.8** |
| **Some College** | **33.1** | **21.7** |
| **Bachelor's Degree +** | **48.7** | **36.1** |

Source: Current Population Survey, October 1993.

Computer use has ben growing most rapidly in homes. Between 1984 and 1993, the number of persons age 18 or over with access to a computer grew by 220%, but the number using a computer at *home* grew even more rapidly, by 289%. Still, even in 1993, only 26% had access to a computer and only 16% actually used a home computer. As we have seen, home computer penetration has now risen to more than 40% of U.S. households, suggesting a continuing growth of home-computer penetration of nearly 15% per year. Obviously, computer penetration cannot continue to grow at this rate for very long because complete saturation would be reached in less than six years at this growth rate.

### v. Internet Subscription and Usage

As recently as 1993, most home use of a computer was for tasks other than email or access to the Internet. The October 1993 Current Population Survey asked respondents how they used their computer, prompting them with the categories — analysis, bookkeeping, graphics, home-based business, household records, "learn to use," programming, sales, and bulletin boards. The only category that is likely to have reflected access to Internet or other on-line services for most computer users would be "bulletin boards." But of the individuals aged 18 or older who used a computer at home for any purpose, only 8.7% of the 16% who used a computer at home indicated that they accessed bulletin boards, reflecting a usage rate of just 1.3% of adults. Far more used their computers for "bookkeeping," "household records," or "learn to use," surely three categories that require little or no on-line usage. It is therefore likely that only a very small number of adults — perhaps fewer than 5% — used the Internet as early as October 1993.

By 1996, home Internet subscriptions had grown substantially. PNR's Request III survey of 31,000 households found that 14.8% of homes subscribed to an Internet service in 1996[40] Among 8,857 telephone-subscribing households surveyed by PNR in 1996 in their annual Bill Harvesting survey, 17.7% indicated that they used the Internet.[41] A January 1997 survey of 48,000 households by PNR and Market Facts, Inc., found that 16% of households were Internet subscribers.[42] The Nielsen March 1997 Home Technology Survey found that 14.9% of its survey households reported that they subscribed to a commercial on-line service.[43]

Commercial estimates of adult Internet access generally conform with the above survey data. Business Week estimates that 40 million people are now Internet users.[44] An April 1997 survey by FIND/SVP estimated that there are 40-45 million users.[45] In November 1996, Louis Harris

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40 Paul N. Rappoport, Lester D. Taylor, Donald J. Kridel, and William Serad, "The Demand for Internet and On-Line Access," unpublished ms, 1997.

41 PNR, *Bill Harvesting III*, 1996.

42 Rappoport *et al.*

43 Nielsen Media Research, *Home Technology Report*, March 1997.

44 http://www.cyberatlas.com/demographics.html.

45 http://etrg.findsvg.com/internet/interest.html.

estimated that there were 35 million adult Internet users, and in October 1996, IDC Research estimated that there were 31.4 million adult users.[46]

Thus, current evidence suggests that about one-sixth of Americans use the Internet. These data are largely confirmed by recent data on the number of subscribers for the leading Internet Service Providers (ISPs) (**Table Appendix D-6**). The ten largest ISPs have approximately 19 million subscribers. Because some of these subscribers may be nonresidential and some residences may subscribe to more than one service, these data are not inconsistent with a total residential penetration of 16%.

**Table Appendix D-6**
**Subscribers to Largest Internet Service Providers, 1997 (millions)**

| Internet Service Provider | Subscribers |
|---|---|
| America On-Line | 8 |
| CompuServe | 5.3 |
| Microsoft Network | 2.2 |
| Prodigy | 1 |
| AT&T Worldnet | 0.9 |
| Netcom | 0.6 |
| Earthlink | 0.3 |
| Concentric | 0.2 |
| MCI | 0.2 |
| Erol's Internet | 0.2 |

Source: *Internet Week,* June 1997 (from ZD Net AnchorDesk)

46 http//:www.idcresearch.com.

Home Internet subscription is directly related to household income in part because computer ownership is related to income. PNR and Associates found that 1996 Internet penetration was less than 5% for households with annual income of $10,000 or less, 23% for households with incomes between $45,000 and $50,000, and 43% for households with annual income of $125,000 or more.[47] Nielsen's March 1997 survey found that 29% of households with less than $10,000 income reported were on-line subscribers, while 72% of households with incomes of $100,000 or more subscribed to such a service.[48] Nielsen's higher penetration rates reflect the fact that income breakdowns are only provided for households who are on-line subscribers at work, home, school, or elsewhere. Internet penetration also depends on occupation. Nearly 30% of persons with professional, managerial, and technical occupations were Internet subscribers, or nearly twice the average for all persons.[49]

Finally, Internet penetration rises with population density, perhaps because of differences in tastes between urban and rural residents. But lower rural penetration could also reflect the fact that Internet connections require a long-distance charge for many rural households.

### w. The Price Sensitivity of Demand for Internet Access and Usage

The decision to subscribe to the Internet requires only that the value of having it, regardless of the intensity with which it is used, exceeds its cost. Indeed, one might subscribe, but rarely log in to one's Internet service. As long as the "option" value of the service exceeds its monthly cost, a household will subscribe.

Using the Internet requires that the subscriber decide that the cost of the connection be less than the value of the service obtained. Because access to the Internet is generally priced at flat monthly rates and the subscriber's residential line is also flat rated, the marginal pecuniary outlay for using

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47 Rappoport *et al.*

48 Nielsen Media Research, *Home Technology Survey*, March 1997.

49 Rappoport *et al.*

the Internet is usually zero.[50] However, the full cost of Internet is not zero, even if one ignores the psychological costs of grappling with a new technology and various Web sites with which one is unfamiliar. The most important cost of using the Internet is obviously the subscriber's time. As a subscriber's income rises, or at least as his/her marginal value of time rises, the cost of sitting at the computer also rises. Thus, we would expect that all other influences equal, Internet usage would decline with income.[51]

The pricing of Internet service has evolved towards a flat-rate system although some providers still offer a number of different usage programs at different flat monthly rates. In 1996, nearly 70% of all Internet users paid $15 or less per month for their service.[52] These low rates are due in large part to the flat monthly telephone rates available to both the residential subscribers and the inbound service on the ISP's lines that connect the subscriber.[53] Given the large share of on-line subscriptions accounted for by America OnLine, there is simply not much variance in the prices faced by subscribers for Internet access. Therefore, it is difficult to estimate the price sensitivity of demand for Internet *access*.

The only econometric study of the demand for Internet connections is a recent one by Rappoport, Taylor, and Kridel.[54] They estimated a logit function with data from PNR's Request Survey for 1996, including a variety of demographic variables for each household, dummy variables for

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[50] Some services that can be accessed over the Internet, such as Amazon.com — a bookstore or United Airlines, impose charges for their services (books and air travel). The analysis in this paragraph does not apply to such services.

[51] Notice that other factors, such as the effect of income on computer purchases and a correlation between education and income, may mask a fall-off in the use of the Internet with income. As we have described above, measured data show an increase in Internet use with income.

[52] Rappoport *et al.*

[53] In many states, there is no flat-rate business service, but even these states do not permit the local exchange carriers to charge for inbound calls from Internet subscribers.

[54] Paul N. Rappoport, Lester D. Taylor, and Donald J. Kridel, "An Econometric Study of the Demand for Access to the Internet," unpublished ms., November 1997.

geographic location, and variables reflecting the household's ownership of other information and communications equipment, such as a fax machine, a cordless phone, or a cellular phone. They found the price-elasticity of demand for access to be -0.18 at a price of $9.95 per month, -0.28 at a price of $14.95 per month, and -0.38 at a price of $19.95 per month.

Rappoport *et al.* have also estimated the price sensitivity of demand for *additional telephone lines* by using Request III survey data for 1996; respondents were asked if they would subscribe to a second line if it conveyed unlimited Internet service at various prices. They found that the arc price elasticity of demand was -0.44 between monthly prices of $20 and $25, prices that are substantially above the current average of Internet service alone. This elasticity rose to -1.0 between monthly flat rates of $25 and $30.

Of greater interest for our purposes is Rappoport *et al.*'s analysis of the responses to questions involving willingness to pay for Internet service at speeds four times faster than "normal" speed, which is likely to be in the 14.4 to 28.8 kbps range. They found that demand for this higher speed service was inelastic (elasticity = -0.51) in the range of $40 to $50 per month but rather price elastic (elasticity = -1.23) in the range of $50 to $60 per month.

The PNR Bill Harvesting database may also be used to estimate the demand for Internet usage. Preliminary estimates suggest that usage has an income elasticity of demand of -0.66, reflecting the fact that higher income individuals find it more costly to sit at their computers than do those with more modest incomes.

### x. Projecting Household Demand for Internet Access and High-Speed Connections

Obviously, any attempt to forecast the demand for Internet access is fraught with peril because the nature of the service is changing rapidly and consumers' ability to grapple with a complex set of equipment and software is evolving rapidly. Predicting the demand for high-speed connections is

even more difficult given the absence of data in an environment in which cable modems and xDSL are only beginning to permeate the residential market.

Nevertheless, we can use the two studies by Rappoport, Taylor, and Kridel and Rappoport *et al.* to make at least an educated guess. Given Rappoport, Taylor, and Kridel's results and the knowledge that approximately 16% of households now subscribe to the Internet at an average price of about $20 per month,[55] we can approximate current Internet demand by the following linear equation:

$$(1)\ Q_I = 0.22 - 0.003\ P_I$$

where $Q_I$ is the share of households subscribing and $P_I$ is the monthly rate. This equation yields price elasticities that are very close to those reported by Rappoport, Taylor, and Kridel. It also predicts that Internet subscription would be equal to 22% of households if the price were to fall to a level near zero. This would represent about 55% of all households with computers and about three-fourths of all households that own computers with a modem. These are reasonable results.

The potential demand for high-speed Internet connections is surely only a subset of all current Internet subscribers. We used Rappoport *et al.*'s results on price elasticities to guide us, but we made our own assumptions about the likely current *extent* of demand. We began by assuming that at another $20 per month, approximately half of all Internet subscribers would opt for a high-speed xDSL service or a cable modem capable of delivering information at five to ten times the current speed of modem-equipped computers if the price were as low as $20 per month. We derived this estimate by observing that equation (1) predicts that a doubling of the cost of the current low-speed service would reduce Internet subscriptions from 0.16 to 0.10 of households. If

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[55] Rappoport, *et al.* report that 70% of households pay $15 or less for their connections, but this excludes usage charges, telephone usage charges, or the charges for a second line where one is used. As a result, we use $20 as an estimate of the average monthly price.

10% of households would continue Internet service at $40 per month, surely it is reasonable to assume that at least 8% of households would opt for a high-speed service at a price of $20 per month (in addition to their Internet or online service charges), even if they had the option to retain their low-speed service at $20 per month.

With these assumptions, a linear demand function is assumed to reflect current *potential* equilibrium demand for high-speed connections:

$$(2)\ Q_{HS} = 0.10 - 0.001\ P_{HS}$$

where $Q_{HS}$ is the share of households demanding high-speed connections at a monthly price of $P_{HS}$. Of course, this level of demand would not be achieved on day one of a new high-speed offering, nor necessarily even within a year. It would take time for households to recognize the availability and potential value of the service(s).

The demand for high-speed services will clearly grow with the development of new Internet services that require large amounts of information transfer and with the growth in computer-equipped households, which in turn will respond to further declines in hardware prices and future growth in household income. Rather than attempting to predict these underlying forces as well as the future course of monthly Internet rates and telephone line charges, we simply assume that household computer penetration and Internet penetration of computer households follow a logistic growth path of the following form:

$$(3)\ f(t) = 0.75 / [1 + exp(-0.25\ t)]$$

where $f(t)$ is the penetration rate and $t$ is calendar time in years with end of year 1997 equal to one. The predicted (exogenous) rate of growth of computer penetration and Internet penetration are shown in **Table Appendix D-7**, beginning with 1998. This assumes that the share of households with a computer asymptotically approaches 0.75 and that the share of these households with

Internet service also approaches 0.75. Therefore, over time total Internet households grow to 0.75 times 0.75 or 0.5625 of all households. Obviously, this is an arbitrary assumption and, if anything, is likely to prove conservative.

To forecast the demand for high-speed connections, we also assumed that household penetration of such connections approaches equilibrium at the rate implied in equation (3), or $1/[1 + e^{-.25\,t}]$. Therefore, we divided equation (2) by $[\,1 + e^{-0.25\,t}\,]$ and multiplied by the square of equation (3) and normalized to 1997 by dividing by 0.178 the assumed penetration rate for online and Internet services in that year:

$$(4)\ Q_{HS,\,t} = \{0.5625/[(1 + \exp(-0.25\ t)]^3 / 0.178\}.[0.10 - 0.001 P_{HS,\,t}]$$

**Table Appendix D-7**
**Predicted Path of Household Computer and Internet-Service Penetration**
**(% of U.S. Households)**

| End of Year | Computer Households | Internet Households |
|---|---|---|
| 1997 | .422 | .178 |
| 1998 | .467 | .218 |
| 1999 | .509 | .259 |
| 2000 | .548 | .301 |
| 2001 | .583 | .340 |
| 2002 | .613 | .376 |
| 2003 | .639 | .408 |
| 2004 | .661 | .436 |
| 2005 | .678 | .460 |
| 2006 | .693 | .480 |

This yielded predictions of household penetration of high-speed services (from any provider) that depend only on the monthly high-speed circuit rental rate. We show these predictions for end of year two (1998) and end of year five (2001) under various assumptions about the year-end 1997 price and the decline rate in these prices in **Table Appendix D-8**.

**Table Appendix D-8**
**Predicted Household Penetration of High-Speed Circuits in Areas in Which Service is Offered**

| Monthly Price-Year-End 1997 (1997$) | Real Price Declines at 5% per Year | Real Price Declines at 10% per Year |
|---|---|---|
| **End of Year 1998:** | | |
| $40 | .049 | .051 |
| $50 | .042 | .045 |
| $60 | .035 | .039 |
| **End of Year 2001:** | | |
| $40 | .102 | .112 |
| $50 | .081 | .103 |
| $60 | .079 | .094 |

## y. Conclusion

No one can know the prospective residential demand for high-speed online or Internet services. So few households now have access to such services that actual data on subscriptions are difficult to obtain and of limited value. Moreover, the very nature of these online and Internet services will surely change as high-speed circuits become widely available. Nevertheless, given the limited data on household computer penetration and the spread of residential subscriptions to online services and two recent unpublished studies of Internet demand, we can proffer estimates of the likely demand for high-speed residential connections. We conclude that about 5% of households

offered the service would subscribe by the end of 1998 if the service were rolled out in 1997 at a price of $40 per month. By year-end 2001, this would increase to between 10 and 11% of households, depending on the real rate of decline in the $40 price. Were the service priced at $60 per month at initial 1997 rollout, only 3 to 3.5% of households would subscribe by the end of 1998 and 8 to 9% by year-end 2001. Because we assumed that computer penetration, online service subscriptions, and high-speed access penetration approach equilibrium very slowly, we view these estimates as extremely conservative.

We also have not considered another important market for DSL services — organizations in smaller buildings where shared tenant Internet access is not feasible. This market includes many small businesses, offices of larger businesses, and libraries.